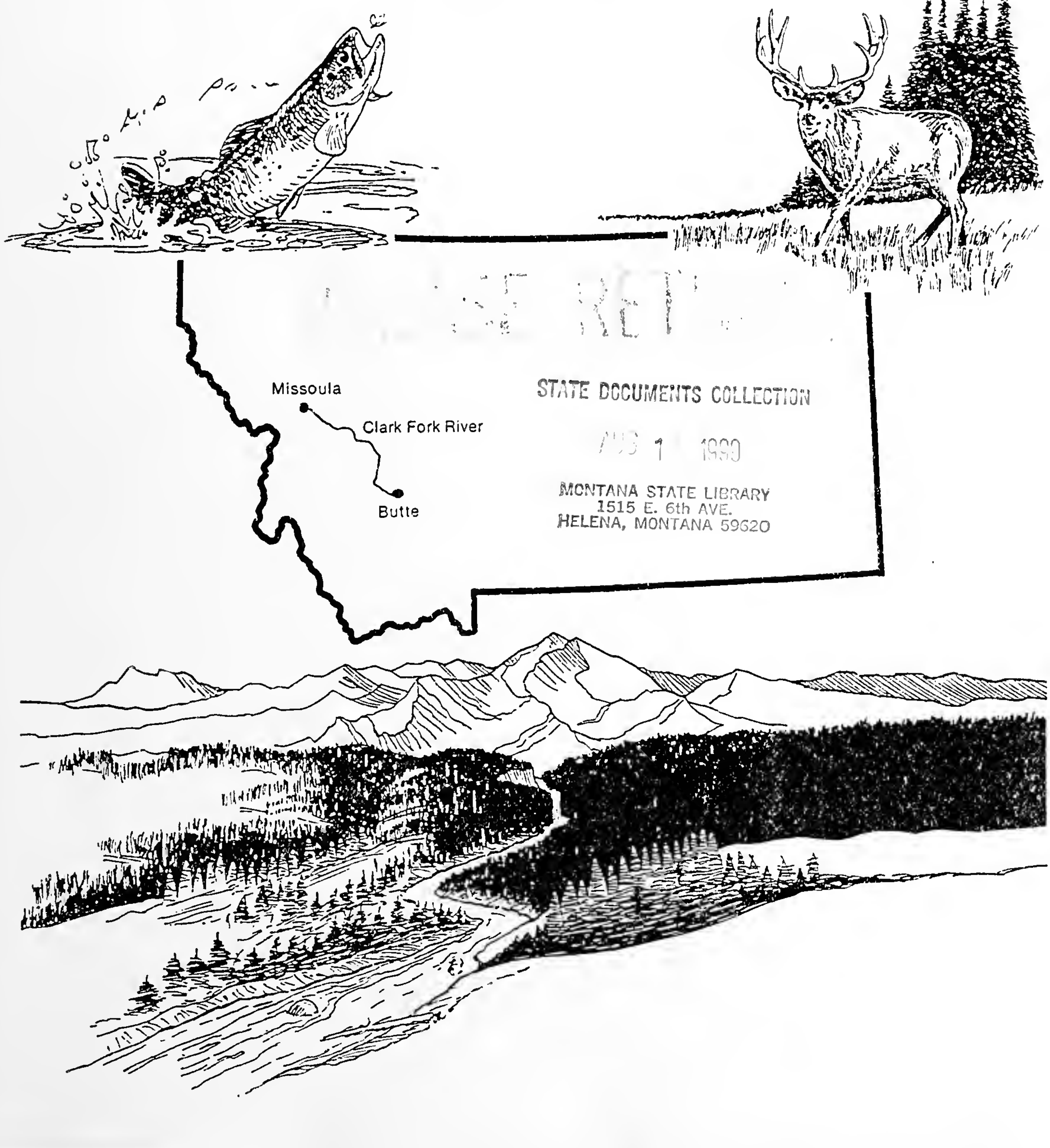
STATE OF MONTANA
RESOURCE DAMAGE PROGRAM

COMMENTS ON ARCO'S REPORTS CONCERNING THE STATE OF MONTANA'S INJURY ASSESSMENT FOR THE CLARK FORK RIVER

PREPARED BY:
TOM BOWLER

OCTOBER 10, 1995



DATE DUE

COMMENTS ON ARCO'S REPORTS CONCERNING THE STATE OF MONTANA'S INJURY ASSESSMENT FOR THE CLARK FORK RIVER

Prepared by:

Tom Bowler

Testifying Expert:

Tom Bowler

Tom Bowler, Metallurgical Eng.
Staff Research Specialist
Montana Bureau of Mines and Geology
1300 W. Park St.
Butte, Montana 59701

Date:

October 10, 1995

Introduction

The following comments have been prepared in response to the critiques and opinions expressed in the report submitted to the United States District Court for Montana by Terence P. McNulty, D.Sc. Information in Dr. McNulty's work alludes to how complicated a problem it is to characterize the nature and quantities of wastes generated from mining processes in the Upper Clark Fork River Basin (UCFRB). Dr. McNulty's report attempts to make much of the fact that mining and processing operations other than copper mining and processing operations were generating wastes in the river basin; and, in fact, that wastes not associated with copper mining had a greater negative impact than those wastes primarily attributable to copper mining and processing. Information provided in the following report would indicate that many of Dr. McNulty's conclusions are erroneous at worst and overstated at best.

Placer Mining Activities

A large portion of Dr. McNulty's report focuses on placer mining in the river basin and associated tributaries, as well as the impacts that placer mining activities had on the river basin. The impact of these placer mining activities appears to be greatly over estimated by Dr. McNulty. On the surface his calculation of the tonnage of waste generated would seem to be reasonable; but when the physical nature of the placer deposits is taken into account a far smaller volume of wastes is more likely to have contributed to sedimentation impacts in the river basin.

The majority of placer operations were on tributaries of the Clark Fork River rather than on the river proper and sediments would have to be transported significant distances to impact the Clark Fork River. Other than the portion of Silver Bow Creek that was placer mined (which did consist of material with a high percentage of fine sediment), the placer areas referred to by Dr. McNulty consist of material with a high proportion of coarse gravel, rocks, and boulders -- typically 60% of the waste is greater than 1 inch in diameter, which contributes no sediment (Lyden, 1948), (McCulloch, 1995 and 1993). Further, approximately ten percent of the material is finer than 100 mesh (.006 inches in diameter), a size that could actually be expected to cause a sedimentation problem at any great distance from the source of placer mining activities (McCulloch, 1995). From my review of Lyden, (1948), all placer mining activities in the Clark

Fork River basin would indicate a total mass of wastes produced by placer mining lower than the 55,000,000 ton figure of total disturbed ground arrived at by Dr. McNulty, and when physical parameters are considered, at most, only ten percent of Dr. McNulty's figure could be considered transportable, which results in an estimate of sediment nearer 5,000,000 tons (McCulloch, 1995).

In summary, these coarse materials are indeed disturbed during mining operations but for all intents and purposes are not transported anywhere, but remain very near their original position. Lyden notes in "Gold Placers of Montana" that among other factors, filling of the Silver Bow Creek channel by mining tailings from sources other than placer mining had virtually eliminated prospects for future placer dredging on this water course (Lyden 1948). This statement provides insight into the degree to which non-placer mining activities overshadow placer mining activities on Silver Bow Creek.

Mercury Contamination Related to Placer Mining in UCFRB

Contamination of the Clark Fork River Basin from mercury attributable to placer mining is another topic discussed by Dr. McNulty. Although mercury is used in many placer operations to assist in gold and silver recovery, there is no evidence to suggest that mercury was widely used in any placer mining in the Upper Clark Fork River Basin. Mercury use was not needed to recover the type of gold prevalent in the area; and certainly not every single yard of placer ground was treated with mercury as suggested in Dr. McNulty's report.

Though Dr. McNulty's estimate of 15% losses of mercury in processing are not unreasonable <u>when</u> mercury is employed in placer mining, he does not elaborate on how he arrived at the amount of mercury used to process one ton of placer gravel in the UCFRB from which the value for losses is generated. The value of 550,000 pounds of mercury losses is greatly exaggerated. No information in the literature provides an estimate of how much mercury could have been used in the Upper Clark Fork River Basin, nor does the literature suggest that mercury was used. No physical evidence exists at former placer sites; for example, mercury flasks and retorts to indicate use of mercury. (McCulloch, 1995). No current placer operations in old districts employ mercury (McCulloch, 1995). The coarse nature of the majority of placer gold particles typically

occurring in the basin, both currently and historically, makes mercury use non-beneficial for the most part (McCulloch, 1995). Finally, published work done by ARCO's own contractor, Heritage Research Center, on placer mining activities within the UCFRB makes no mention of mercury use in placer mining in the UCFRB. (Heritage Research Center).

Early Butte Silver Processing Activities

Dr. McNulty's report provides some estimates of wastes generated by silver ore processing facilities in Butte. Dr. McNulty provides an estimate of 1,400,000 tons of tailings generated from silver processing facilities in Butte. The notion that all of these wastes remained in place is unlikely. Due to the probable poor silver recovery from processes employed at some of the facilities, much of the tailings material was probably later re-processed by other methods (Wilcox, Undated and Mineral Res. of U.S.). Also, Wilcox, (Undated) provides information which indicates that many of the silver processing facilities ran for a shorter duration than Dr. McNulty suggests. Furthermore, Smith, (1953) details the evolution of many of these mills, describing how most started with a far lower production capacity than assumed by Dr. McNulty and expanded over time. Finally, the 90% plant availability seems quite high for the type of plant he is describing. All of these factors indicate that production from these silver processing facilities is quite difficult to estimate and is likely to be lower than the 1,400,000 ton figure provided by Dr. McNulty.

Waste Generation at Butte Copper Processing Facilities

Dr. McNulty also devoted a great deal of work in his report to account for all of the different sources of processing wastes derived from hard rock mining in the UCFRB and to make careful distinctions between types of wastes and the parties who were generating those wastes (for example: copper processing facilities, lead/zinc processing facilities, and silver processing facilities). Unfortunately, in some cases he did not carry the work far enough, (for example: not accounting for wastes that were re-processed by the Anaconda Company) and in other areas he attempted to make distinctions that probably do not exist. Complex ore mineralogy, handling and re-handling of wastes, variations in types and sources of plant feed materials, questionable plant performances, materials shipped from other areas of the state, the nation, and the world that were

metallurgically treated by the Anaconda Company and other plants in the Butte are all confounding factors not mentioned by Dr. McNulty in his estimates of waste volumes and origins.

Complex Ore Mineralogy

Evidence in the literature contradicts many of the conclusions reached by Dr. McNulty. On page 11 of his report, Dr. McNulty presents a discussion of a very general model of the geology of the Butte District, which is essential to any discussion of mining and ore processing. However, his diagram and presentation leave out several key elements that have major ramifications when he later discusses the distinctions between silver, copper, and lead/zinc mineral processing facilities. Firstly, the diagram and accompanying discussion are over simplified. A more detailed discussion in Meyer, (1968) reveals that the boundaries between the zones shown in Dr. McNulty's diagram are not so distinct and that the model varies in three dimensions and not simply two dimensionally. Another detailed discussion of Butte District geology (Thompson, 1973) specifically refers to " a broad zone of mixed copper and zinc sulfides of the deeper underground mines." Sales, (1913) and Weed, (1912) also provide insight about the complex nature of mineralization in the Butte mines.

This information becomes critical when Dr. McNulty implies that tailings materials from a known copper ore mill -- such as the Colorado Mill Tailings -- must necessarily be adulterated by materials from a lead/ zinc mill due to the levels of zinc found in the material (as he actually does imply in paragraph 5 on page six of his report). A particular mine in the Butte District would certainly be classified as primarily a copper, silver, or lead/zinc mine but that does not mean, absolutely, that no zinc ever ended up at a copper mill from ore mined at a primary copper mine. Peters, (1884) and Weed, (1912) specifically point out that the primary mine providing ore for the Colorado Smelter did not really fit into the categories of copper mine or silver/zinc mine, but had an ore mineral composition somewhere between these two classifications. Also, many mines located in the geographic area described as the "Copper Zone" of the Butte District began life exclusively as silver mines (Peters, 1884); producing copper ore only as greater depths were reached during the mining process.

Furthermore, if ore containing intolerable lead and zinc values was segregated at the mine, the material could very conceivably have been dumped on a waste rock dump at the mine. If waste rock dumps are higher in lead and zinc than in copper the reason could well be that copper ores were sent on to the mill while mined materials high in lead and zinc were preferentially discarded at mine sites by the mine operator. This would confound the assertion made by Dr. McNulty in item (3) on page 6 of his report that assay values (which contain higher levels of lead and zinc than than copper) taken from table 2-2 of the "Aquatic Resource Injury assessment Report", (Lipton, 1995), indicate that lead/zinc processes were dominant waste contributors, not copper producers. In addition, Dr. McNulty's assertion cannot be so simply made from these values because the weights of each type of waste are not reported in this table. If ten tons of lead/zinc tailings were assayed and one hundred tons of copper tailings were assayed simple averaging of the assay values would unquestionably exaggerate the influence of a much smaller volume of lead/zinc wastes.

"Notes on the Metallurgy of Copper of Montana by Hofman (1903)", cited by Dr. McNulty, actually profiles a class of ores processed in copper milling and smelting at Butte plants as "silver-copper ores" with the two zinc minerals wurtzite and sphalerite listed as common constituents in these ores. Emmons, (1897) provides information that some second class copper ores, as described in Hofman, (1903), contained 2% zinc. As late as 1976 a paper describing operations at the Anaconda Company's Weed concentrator in Butte (Palagi 1976), without question a copper mining operation, states that the "Berkeley Pit is a very nonhomogeneous mine with respect to ore type and mineralization." Additionally, the paper notes that zinc exists in the ore and that no attention is paid to the recovery of zinc (Palagi, 1976). If a modern, highly efficient, copper mining operation paid but passing interest to the zinc content of the ore being processed, why would fledgling copper mills and smelters with one hundred years less technical experience in mineral processing be expected to track and reject zinc in their mill feed with the degree of precision that Dr. McNulty's report implies?

With the advent of modern froth flotation as employed in the recovery of copper sulfide minerals at the Washoe Reduction Works in the 1920's and several decades of operational experience in copper processing, the ability to selectively recover copper while excluding zinc and lead bearing minerals was greatly enhanced over

the older gravity separation methods employed at the Old Works and in Butte. This explanation is consistent with the relative increase of zinc to copper values in the tailings of the Opportunity Ponds when compared to wastes at the Old Works as presented by Dr. McNulty on page (7) of his report. Copper could be more completely removed from tailings while unwanted lead and zinc could be more effectively directed to the tailings. Froth flotation finally allowed the processor to reject the undesired zinc and lead that was inevitably present in some copper ores mined in Butte.

Other Mineralization

Dr. McNulty does correctly assert that cadmium is found in conjunction almost exclusively with the zinc mineral sphalerite. However, he incorrectly concludes that any cadmium contamination found in wastes in the UCFRB indicates a waste material from a lead/zinc processing facility. The references cited above Meyer, (1968); Weed, (1912); and Sales, (1913) make a strong case that in the normal course of mining, enough ore containing both copper and sufficient zinc minerals, including cadmium associated with the zinc mineralization, was sent to a "copper mill", producing a tailings with cadmium levels not unlike those found today in material such as the Colorado Tailings.

Laist, (1913), speaks of both the zinc and manganese content of the feed material for the copper smelter of the Anaconda Company in Anaconda -- both elements which Dr. McNulty argues on pages (6) and (7) of his report were not present in copper ores. Sales, (1913) and Weed, (1912) also remark on the manganese found in Butte copper ores which Dr. McNulty contends was unique to lead/zinc and silver types of ore from the Butte District. (Weed, 1912) also points out that manganese ores were mined in Butte for use as a smelting reagent in copper smelters. These ores were also desirable for the silver that they contained. Here is evidence that significant amounts of manganese ore was present at copper smelters in Butte, not for the metal value of copper in the ore but because the material had properties beneficial for recovering copper in the smelting process and contained precious metals as well. These manganese ores used at copper smelters would account for manganese contamination found at these sites which Dr. McNulty feels must be explained by other means.

Mill and Smelter Feed Materials from Sources Other Than

Mines in Butte

A further complication in accounting for wastes based on signature elements (cadmium for instance) is the fact that most mills and smelters bought ores from other sources and introduced these ores into the waste streams along with ores from the mines in Butte. (Mineral Res. of U. S.) As an example, annual reports of the Anaconda Copper Mining Company (Ryan), for the years 1921 through 1924 report that from 54,000 to 345,000 tons per year of ore from outside sources were purchased by the Anaconda Company or processed for other entities at the copper processing facilities of the Anaconda Reduction Works. These reports also indicate that from 7,000 to 25,000 tons per year for the years 1921 through 1924 of materials from old plants at Butte and Anaconda were re-processed at the Reduction Works, as well as a couple of thousand tons of feed material for the zinc reduction works from old plants in Butte. Bolles, (1954) lists a total of approximately 4 million tons of tailings from Butte plants and 2.75 million tons of old mine dumps from Butte that were re-processed at the Washoe Reduction works during World War II to meet copper demands of the time. Of the many facilities for which Dr. McNulty feels the state has not accounted for waste, much was re-processed by the Anaconda Company using more modern methods as indicated by these annual reports and the Bolles report (Ryan, 1921-1924; Bolles, 1954: and Mineral Res. of U. S.).

Also unknown is how much of the waste from other plants was moved by the Anaconda Company during mining of the Berkeley Pit and Continental Pit which encompass much of the area where many of these mills and smelters were located, including the mill of the Butte and Superior Company. Additionally, hundreds of thousands of tons of old tailings from earlier less efficient milling operations in Anaconda were noted to have been re-processed. (Anaconda Annual Reports, 1921-1924; Laist, 1944; Mineral Res. of U. S.).

Slag Wastes

Dr. McNulty asserts in item (5) on page 6 of his report that metal values of wastes at the Butte Reduction works and the Colorado tailings must be questioned due to the possibility that these wastes have commingled with other wastes from upstream sources. An examination of smelter slags from this area can provide insight into the amounts of zinc and cadmium that were being processed by facilities of the Butte Reduction Works and the Colorado Smelter. The

advantage of this analysis is that there can be no question that slag waste has been influenced by any lead/zinc wastes and is, therefore, without question typical of wastes from these facilities. Smelter slag assays dated October 14, 1899 of the Colorado Smelter from (Laist, 1933) show that the slag contains 12% zinc. This zinc had to have been in the smelter feed material at approximately the same concentration, which shows that a great deal of zinc was being handled at the smelter. In fact other values provided by this same source show the typical concentrate at the smelter had only ten percent copper -- two percent less than the zinc content of this slag. Levy, (1912) also provides a figure of a typical Butte concentrate containing 10% copper although no value for zinc is noted. Taggart, (1944) also notes Anaconda Company concentrates of around 13% copper. Even Laist, (1929) an Anaconda Company metallurgist, one of Dr. McNulty's own references, talks about concentrates of 10% copper content being produced from plant feed of 4.5% copper content. All of these percentages of copper in concentrates are approximately half of the 20% number presented by Dr. McNulty for concentrates produced before 1915. Smelter slags are still present in the area around the Butte Reduction Works and zinc values of 2.5 percent and cadmium values of 18 parts per million have been measured in the slag. (CH_2M Hill and Chen-Northern, 1990). These values are completely consistent with levels of zinc and cadmium found in tailings material from the Plants of the Butte Reduction Works and Colorado Smelter suggesting no biasing effect from other materials transported from other facilities as suggested by Dr. McNulty.

Low Grade Copper Ores

When Dr. McNulty provides his equation and parameters for the calculation of tailings produced from low grade copper ores on page 28 of his report, he fails to note that the values are typical of an operation of only the last few decades at best. Dr. McNulty's cited ore grades of 1 percent copper, concentrate grades of 28 percent copper and recoveries of 90% on page 28 of his report are figures that cannot realistically be used to make estimates of waste volume for the entire operational history of the Anaconda Company flotation operations. Flotation was a brand new technology in the 1920's and the operators then could not have reasonably been expected to achieve the kind of performance in concentrate grade and plant recovery as indicated by the numbers on page 28. The process has evolved many times since the 1920's. The use of present day values in tonnage estimates for the entire history of milling low grade

copper ores is a shaky proposition at best. Even in the 1970's, Anaconda Company copper recoveries of only 80 percent were being achieved at the Weed concentrator in Butte (Palagi, 1976).

All of the discussion in the preceding paragraphs on copper mining and processing indicates the Butte mines and Butte and Anaconda processing facilities were accustomed to mining, milling, and smelting a wide variety of materials with widely varying results over time and Dr. McNulty's arguments (expressed on page 6 of his report) in paragraphs: (3), lead/zinc operations are responsible for the majority of mining and mineral processing wastes in Butte; (4), cadmium is an absolute indicator that supports the argument in paragraph three; (5), wastes from two known copper processing facilities may not really be from these facilities; and (7), wastes at facilities in Butte are not identical to wastes at the Old Works in Anaconda and thus must be from silver, zinc, lead, or manganese producers are not compelling. There is no doubt that zinc was and is an undesirable constituent in copper milling and smelting but this in no way proves that a copper processing facility rejected ore based solely on the fact that the ore contained zinc as Dr. McNulty implies on pages 12 and 13 of his report.

Butte Zinc Operations

Dr. McNulty talks a great deal about typical wastes generated by various processing operations. On page 4 of his report (section 3), Dr McNulty notes typical levels of lead and zinc in tailings from two Butte zinc mills of 1 to 5 percent. A comparison of tailings from a lead/zinc operation known to have employed modern froth flotation, such as the Marget Ann tailings, provides more information about "typical" wastes from lead/zinc facilities in Butte. Assay values from tailings at the Marget Ann Mill show zinc levels of from 0.05 to 0.25 percent, lead values of from 0.006 to 0.2 percent and cadmium levels of from 3 to 20 parts per million. (Camp Dresser & McKee Inc. 1988). All of these values are far lower than values cited by Dr. McNulty as being typical of zinc tailings from Butte plants. In fact, these values are lower than "typical" values found at copper processing facilities. These values should certainly be included in any discussion of typical zinc wastes and how the wastes may have influenced copper processing wastes.

Furthermore, Taggart, (1944) provides a table showing that the Timber Butte mill produced three concentrates; zinc, lead, and copper/pyrite. In the case of the Timber Butte Mill, we see a primary zinc/lead processing facility also making a copper concentrate, further blurring the lines between what type of materials were processed at different facilities. Furthermore, with three concentrates being produced, Dr. McNulty's equation for estimating tailings weights for zinc facilities on page 27 of his report falls completely apart. To account for three different products a far more rigorous mathematical manipulation is required. One fact is certain, however, the volume of zinc process tailings would be much lower than the figure produced in Dr. McNulty's equation if the weights of a lead concentrate and a copper/pyrite concentrate are deducted from the tailings weight in addition to the weight of zinc concentrate which has already been subtracted in the equation. Once again a physical examination of all of these wastes must be undertaken in any discussion of lead/zinc tailings influencing downstream wastes. Of the estimated tonnages of tailings generated by these mills how much material can still be accounted for in the proximity of the mill sites? Certainly almost all of the material would have to have been transported downstream to have any biasing affect on the enormous volume of copper wastes generated in the basin.

Mine Wastes in Other Areas of UCFRB

On page five of his report Dr. McNulty mentions other mining operations in the Flint Creek valley and other tributary basins of the UCFRB. He also presents a figure of 1,500,000 tons of tailings and waste generated by mining in the Flint Creek drainage, with the implication that these materials had significant influence on the Clark Fork River Drainage. A currently ongoing project at the Montana Bureau of Mines is directed toward assessing many of the very sites to which Dr. McNulty alludes. Some of these wastes have been removed in the past and ironically some were re-processed by the Anaconda Smelter [some wastes from the Granite Bi-Metallic for example (Mineral Res. of U. S. and McCulloch, 1995)]. Much of the waste generated in this mining district is still in place indicating that the material hasn't been and isn't seriously influencing sediments in the Clark Fork River Basin. An examination of the streambeds below the Flint Creek mining areas show no evidence that large amounts of tailings from this area have been transported to the Clark Fork River. Many of the mines alluded to in the United States Bureau of Mines (USBM) MILS (Mineral Industry Location System) database

information owed their existence to the existence of the Anaconda Reduction Works and Smelter to which they sold ore, thus making the Anaconda Company the processor of much of the ore material from small mines located on tributaries of the Clark Fork River (Pardee and Schrader, 1933; MBMG Files; and Mineral Res. of U. S. and Emmons & Calkins, 1913). From my personal knowledge of the U.S.B.M.'s MILS database obtained during the course of my work assessing inactive mines, I can report that this is a questionable source of information. Many of the site locations are inaccurate (some listed sites with location precision of ten kilometers). The database makes no distinction between mineral claims that never had any mining activity and productive operations that may have been developed to the extent of having had an on-site mill. There is a very high probability that many of the 206 mines in other drainages that Dr. McNulty cites from MILS are nonexistent. Without a doubt a volume of tailings and waste far less than the 1,500,000 tons Dr. McNulty attributes to the Flint Creek drainage is contributing to the Clark Fork River. (Metesh, 1995).

Conclusions

In summary, a great deal of information from reliable sources, many of the same sources cited in Dr. McNulty's report, is available which contradicts a number of the opinions expressed by Dr. McNulty in his report. Simply put, the Butte district is primarily a copper producing mining district with notable lead, zinc, and silver mineralization and production. The argument that mining other than copper mining generated most of the waste problems in the UCFRB is weak. Dr. McNulty's attempt to calculate tailings volumes for various Butte and Anaconda operations is highly questionable based on the assumptions and simplifications that form the basis of Dr. McNulty's analysis.

References

1) Adams, R. W. and Others. 1986. "Mining Chemicals Handbook".

2) Appling, R. N. and Others. 1980. "Smelter and Ore Purchases and General Contract Agreements"; prepared by Western Field Office of United States Bureau of Mines.

3) Bender, L. V. and Goe, H. H. 1933. "Production of Arsenic Trioxide at Anaconda"; Transactions of AIME.

4) Biwas, A. K. and Davenport, W. G. 1976. "Extractive Metallurgy of Copper".

5) Blake, William P. 1887. "Silver Mining and Milling at Butte, Montana"; pages 38 to 45 of Transactions of AIME.

6) Bolles, John. 1954. "Fourteen Years of Progress at the Copper Concentrator in Anaconda"; Anaconda Company Internal Document.

7) Braden, William. 1896. "Notes on the Handling of Slags and Mattes at Smelting Works in the Western United States"; Transactions of AIME.

8) Camp Dresser & McKee Inc. 1988. "Butte Soils Screening Study"

9) CH2M Hill, Inc. and Chen-Northern, Inc. 1990. "Draft Final Silver Bow Creek CERCLA Phase II Remedial Investigation Data Summary Area I Operable Unit Volume I"

10) Emmons, S. F. ,Weed, W. H. and Tower, G. W. 1897. "Butte Special Folio"; Montana. Folio 38 of the "Geologic Atlas of the United States" published by United States Geological Survey.

11) Emmons,W. H. and Calkins, F. C. 1913. "Geology and Ore Deposits of the Philipsburg Quadrangle Montana"; Professional Paper 78; published by the United States Geological Survey.

12) Essig, D. A. and Moore, J. N. 1992. "Clark Fork Damage Assessment Bed Sediment Sampling and Chemical Analysis Report".

13) Gaudin, A. M. 1939. "Principles of Mineral Dressing".

14) Hofman, H.O. 1903. "Notes on the Metallurgy of Copper of Montana" pages 258 to 316 of Transactions of American Institute of Mining Engineers (AIME).

15) Kerr, Mark -- Natural Resource Damage Program. 1995. Personal Communication.

16) Koch, E. G. and Sahinen, U. M. Undated. "The Evolution of Copper Mining in Butte"; publication of the Montana Bureau of Mines and Geology.

17) Lamborn, Robert H. 1860. "A Rudimentary Treastise on the Metallurgy of Copper".

18) Laist, Frederick. 1913. "Chemistry of the Reduction Processes in Use at Anaconda, Montana"; pages 806-817 of Transactions of AIME.

19) Laist, Frederick and Others. 1929. "Modern Metallurgical Miracles" and Other Articles from August 24 issue of "Engineering and Mining Journal, E&MJ".

20) Laist, Frederick. 1933. "History of Reverberatory Smelting in Montana, 1879-1933"; pages 23 to 87 of "Copper Metallurgy 1933" published by AIME.

21) Laist, Frederick. 1944. "Metallurgical History of the Anaconda Copper Mining Company"

22) Levy, Donald M. 1912. "Modern Copper Smelting" page 63.

23) Lipton, Joshua and Others. 1995. "Aquatic Resources Injury Assessment Report".

24) Lyden, Charles J. 1948. "The Gold Placers of Montana", Memoir 26; Montana Bureau of Mines and Geology Publication.

25) Montana Bureau of Mines and Geology -- Montana Mine Information Files.

26) McCulloch, Robin 1993. "Montana Placer Mining BMP's", Special Publication 106; Montana Bureau of Mines and Geology Publication.

27) McCulloch, Robin -- Staff Field Agent and Mining Engineer Montana Bureau of Mines and Geology 1995. Personal Communication.

28) Metesh, John and Others. 1995. Unpublished and ongoing research for Abandoned - Inactive Mines Program; Montana Bureau Of Mines and Geology.

29) Meyer, Charles, Shea, Edward P. and Others 1968. " Ore Deposits at Butte, Montana"; pages 1373 to 1416 of "Ore Deposits of the United States, 1933-1967 ", Volume II. AIME publication.

30) "Mineral Resources of the United States" 1880-1980. publication of the United States Geological Survey.

31) Mitchell, W. E. 1943. " Special Report - Treatment of Miscellaneous Materials"; Collection of Anaconda Company Memoranda.

32) Palagi, C. G. , Stillar, S. S. 1976. "The Anaconda Weed Concentrator" pages 1029 to 1042 of ." Flotation -- A. M. Gaudin Memorial Volume, Volume II; published by AIME

33) Pardee, J. T. and Schrader, F. C. 1933. "Metalliferous Deposits of the Greater Helena Mining Region Montana"; U.S.G.S. Bulletin 842

34) Peters, E. D. Jr. 1884. "The Mines and Reduction Works of Butte City, Montana." ; from "Mineral Resources of the United States"

35) Rickard, T. A. 1921. "Concentration by Flotation" pages 23 to 25 and 120 to 124.

36) Ryan, John D. , Kelley, Cornelius F. 1921, 1922, 1923, 1924. "Report of the Anaconda Copper Mining Company"

37) Sales, Reno H. 1913. " Ore Deposits at Butte, Montana"; pages 3 to 109 of Transactions of AIME.

38) Smith, Ralph I. 1953. "History of Early Reduction Plants of Butte, Montana"; Reprint No. 2, MBMG publication

39) Steele, C. H. 1946. "Report on Secondaries - Production to April 1, 1946 and Reserves April 1, 1946"; Anaconda Company Internal Document.

40) Taggart, Arthur F. 1920. "A Manual of Flotation Processes"

41) Taggart, Arthur F. 1944. "Handbook of Mineral Dressing --Ores and Industrial Minerals"

42) Thompson, Byrl T. 1973. "Distribution of Primary Mineralization and Hydrothermal Alteration Within the Berkeley Pit, Butte District, Montana"; Section L of "Guidebook for the Butte Field Meeting of Society of Economic Geologists".

43) Trauerman, Carl J. and Waldron, Cecil R. 1940. "Directory of Montana Mining Properties"; Memoir No. 20, publication of Montana Bureau of Mines and Geology.

44) Twidwell, L. G. and Others. Undated. "Unit Processes in Extractive Metallurgy - PYROMETALLURGY"; Modular Tutorial Course supported by the National Science Foundation.

45) Weed, Walter Harvey. 1912. "Geology and Ore Deposits of the Butte District, Montana"; U.S.G.S. Professional Paper 74.

46) Wilcox, W. J. and Gillie, John M. Undated. "Smelters, Mills and Concentrators - Butte, Montana"; compiled from information provided by General Office, A. C. M. Co.

47) Wills, B. A. 1985. "Mineral Processing Technology, 3rd Edition".

48) Winchell, Alexander N. 1914. "Mining Districts of the Dillon Quadrangle, Montana and Adjacent Areas"; Bulletin 574, a publication of United States Geological Survey.